Triggered di-hadron correlations in Pb–Pb collisions from the ALICE experiment

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Abstract. Angular correlations between unidentified hadron trigger and associated particles are measured by the ALICE experiment for $0.5 < p_T^{t,a} < 15$ GeV, where $p_T^t \geq p_T^a$. The pair correlation shapes are examined in a variety of centrality categories for pairs in $|\eta| < 1.0$ where $|\eta^t - \eta^a| > 0.8$. A series of two-particle Fourier components $V_{n\Delta} \equiv \langle \cos(n\Delta\phi) \rangle$ are extracted from the long-range azimuthal correlation functions. The sum of $n < 6$ terms match the data. For each n, a fit is applied over all p_T bins simultaneously to test the collectivity hypothesis $V_{n\Delta} \simeq v_n^t \, v_n^a$. The factorization holds at $p_T^{t,a}$ below approximately 4 GeV but breaks progressively at higher momenta. The divergence between the data and the global fit quantifies the onset of nonflow dominance in long-range correlations due to the away side jet. The v_n values from the global fit are in close agreement with results from more established methods. At higher p_T where jet correlations dominate, the modification of conditional yields in central Pb–Pb collisions is measured with respect to pp (I_{AA}) and with respect to peripheral events (I_{CP}). Significant suppression is observed on the side opposing the trigger, while a moderate enhancement is measured on the near side.

The distribution of angles $\Delta\phi$ and $\Delta\eta$ between charged hadron trigger particles and their associated partners provides valuable information on a variety of physical processes in heavy ion collisions. The correlation function, $C(\Delta\phi, \Delta\eta) \equiv N^{AB}_{mixed}/N^{AB}_{same} \times (dN^{AB}_{same}/d\Delta\phi d\Delta\eta)/(dN^{AB}_{mixed}/d\Delta\phi d\Delta\eta)$, describes the shape. The per-trigger conditional pair yield is given by $Y \equiv (N^{AB}_{same}/N^A).C(\Delta\phi, \Delta\eta)$ (although not described here, acceptance and efficiency correction factors are also included in practice). At $\sqrt{s_{\rm NN}} = 2.76$ TeV, Pb–Pb events exhibit a rich evolution with p_T of the trigger and

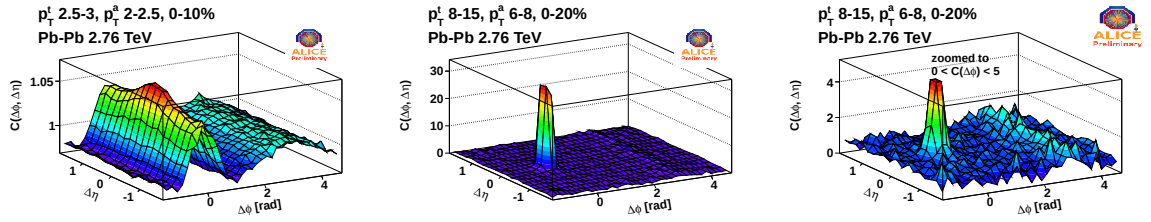

Figure 1. $C(\Delta\phi, \Delta\eta)$ at intermediate p_T (left) and at higher p_T (center, vertical axis zoomed at right).

associated particles (p_T^t, p_T^a), as indicated in figure 1. At a few GeV and higher, a peak

at $(\Delta\phi, \Delta\eta) \approx (0, 0)$ mainly from jet fragmentation grows in correlation strength with p_T^t and p_T^a , dominating the distribution at high p_T. The away side ($\Delta\phi \approx \pi$) is reduced since the recoil jet suffers a swing in pseudorapidity due to differences between momenta of the incoming hard-scattered partons. A ridge feature dominates the near side at 2-3 GeV, but becomes indistinguishable from the background at higher p_T. A double-peaked away

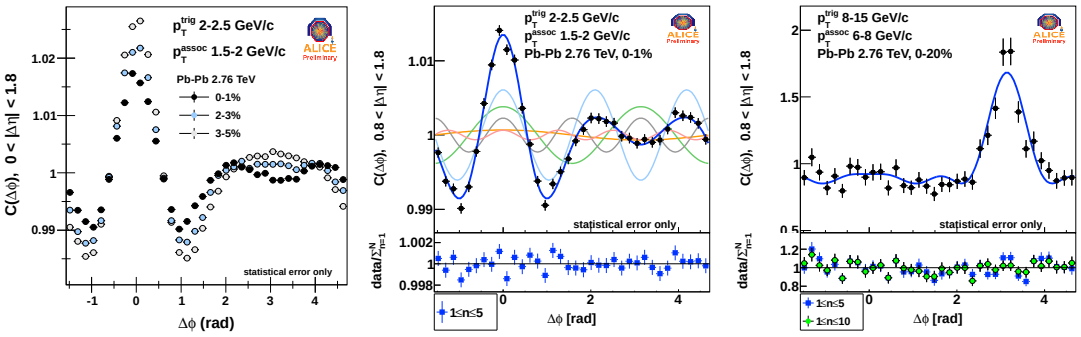

Figure 2. Azimuthal projections of $C(\Delta\phi, \Delta\eta)$ for $0 < |\Delta\eta| < 1.8$ (left) and $0.8 < |\Delta\eta| < 1.8$ (center, right).

side structure is visible in azimuthal projections of the most central collisions (figure 2, left). Excluding the near side jet by requiring $|\Delta\eta| > 0.8$, the near side ridge is prominent and the doubly-peaked away side persists (figure 2, center). The latter becomes a single narrow peak at higher p_T, which is extended in $\Delta\eta$ and has a shape consistent with jet fragmentation (figure 2, right). The question naturally emerges as to the relative contributions of the correlation sources as a function of momentum. To this end, we study the Fourier components of $C(\Delta\phi)$: $V_{n\Delta} \equiv \langle \cos n\Delta\phi \rangle = \sum_i^N w_i \cos n\Delta\phi / \sum_i^N w_i$, where w_i is the content of $\Delta\phi$ bin i; see for example figure 2 (center). In central events, including $n > 5$ gives only a marginally improved match, particularly below $\sim$ 3-4 GeV. At p_T^t (p_T^a) above 8 (6) GeV, where the jets are more collimated, higher terms may be less negligible. However, Fourier-decomposing a narrow Gaussian recoil jet peak, although mathematically well-defined, is less intuitive as a descriptive mechanism compared to lower p_T cases, where the first few terms each have distinct physical interpretations.

If two-particle correlations arise from an event-wide collective response to initial state anisotropy, then all particles are "pushed" by the same global mechanism, and should participate in a pattern of anisotropy described by a single $v_n(p_T)$ curve. Thus, pair correlations would be a simple factorizable product of the single-particle bulk anisotropies [1]:

$$V_{n\Delta}(p_T^t, p_T^a) = v_n(p_T^t) v_n(p_T^a) \tag{1}$$

In contrast, anisotropy from particles correlated only through localized effects such as resonance decay or jet fragmentation (plus medium response) would not be expected to factorize, since such mechanisms have weaker direct dependence on global symmetry properties (although effects such as pathlength-dependent energy loss can play some role).

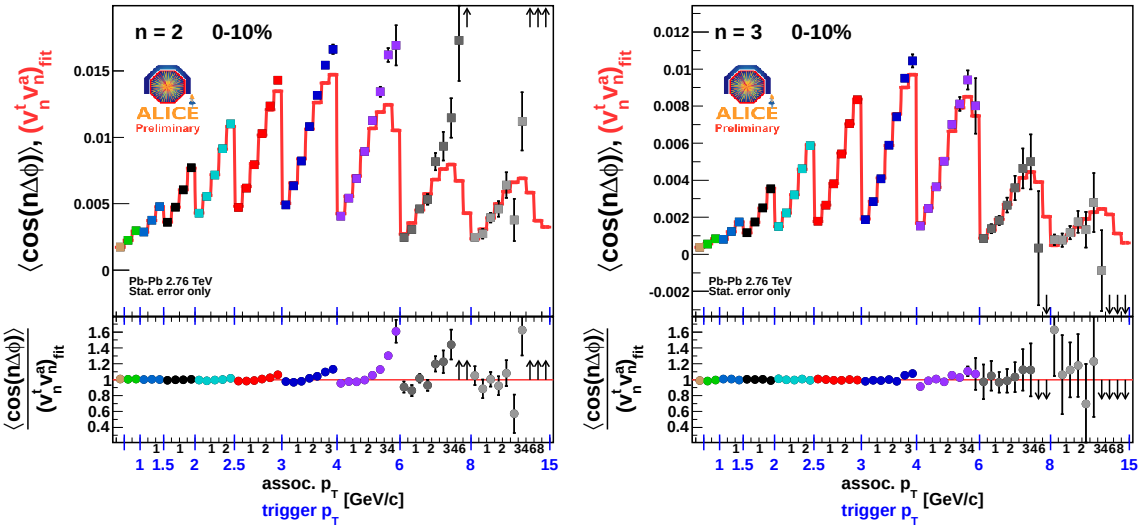

Figure 3. Global fits to $V_{2\Delta}$ and $V_{3\Delta}$ in 0-10% Pb–Pb colllisions for $|\Delta\eta| > 0.8$.

The factorization ansatz of eq. 1 is a testable relation, opening the possibility to distinguish between collective and local correlation contributions as a function of centrality and p_T. For each n, the set of all $V_{n\Delta}(p_T^t, p_T^a)$ points was fit simultaneously with the right-hand side of eq. 1 for a variety of centrality categories. Examples are shown in figure 3. The measured $V_{n\Delta}$ points and the global fit generally agree for $n > 1$

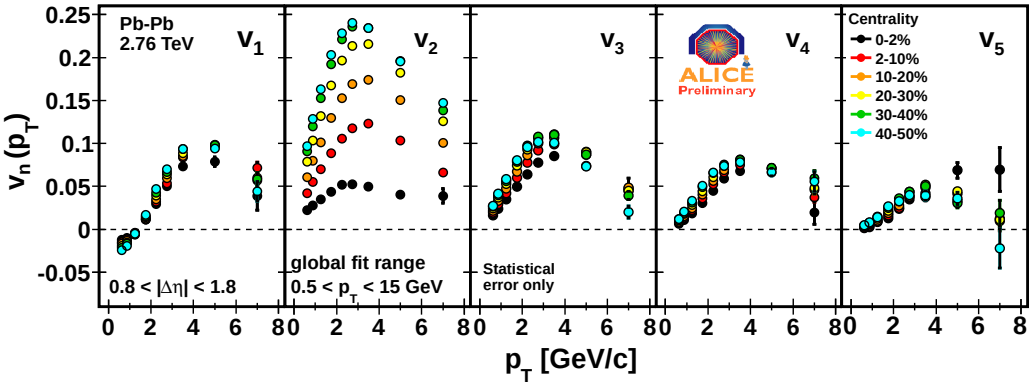

Figure 4. v_n coefficients for $n \leq 5$ produced from the global fit.

for p_T^t, $p_T^a < 4$ GeV in central events. For all n, the global factorization products tend to increasingly deviate from the data with rising p_T and centrality, reflecting growing nonflow contributions to the anisotropy. The factorization for v_1 does not hold as well as the others at any centrality or p_T. A dipole contribution from p_T conservation may be partially responsible. Corrections for this have been proposed [3], but not applied here; its inclusion is an area of current study.

To the extent that collectivity is validated by the global fit, the resulting parameters take a physical interpretation as $v_n(p_T)$ (figure 4). The global fit v_n values agree with those obtained by more standard "flow" analyses such as $v_n\{SP\}$ [2] for $2 \leq n \leq 5$.

The modification of near- and away-side conditional yields from observables such as $I_{AA} \equiv Y_{Pb-Pb}/Y_{pp}$ or $I_{CP} \equiv Y_{\rm central}/Y_{\rm periph}$ provide important constraints on energy loss models, particularly as a complement to R_{AA} . At p_T^t (p_T^a) > 8(4) GeV, the correlations are dominated by jets and the flow correlations are far smaller in comparison. In this regime, the jet yield can be extracted with minimal biases from assumptions about the shape and background level. The result of I_{AA} at 2.76 TeV is shown in figure 5. The

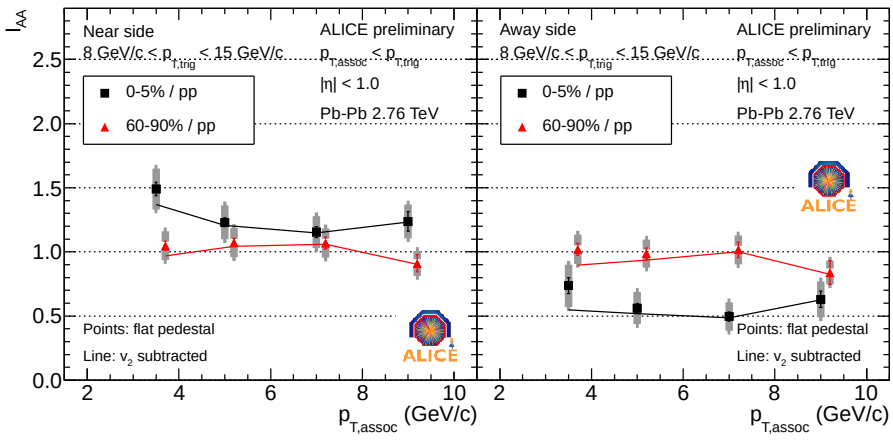

Figure 5. Near (left) and away-side (right) I_{AA} for 0-5% and 60-90% centralities, where $8 < p_T^t < 15$ GeV.

small difference between using a uniform background shape (shown as points) and a v_2-modulated background (solid lines) shows that background shape assumptions do not lead to large uncertainties. We find an enhancement of ∼20% in central Pb–Pb vs. pp on the near side, and suppression leading to $I_{AA} \approx 0.5$-0.6 on the away side. I_{CP} was measured and also leads to the same conclusions. Further discussion of the analysis and interpretation of these results, as well as the I_{CP} result, can be found in [4].

In this presentation, the shape evolution of triggered two-particle correlations was quantified via Fourier analysis. We conclude that the correlation features of rapidity-separated pairs with momenta below about 4 GeV, such as the ridge and the double-hump structure, are most consistent with expectations from collective (i.e. hydrodynamic) response to anisotropic initial conditions, while at higher momenta, the breaking of $V_{n\Delta}$ factorization signals the onset of local, rather than global, nonflow correlations. In addition, the near-side enhancement and away-side suppression suggest the presence of a dense medium causing a loss of energy by hard-scattered partons.

References

[1] Matthew Luzum. Collective flow and long-range correlations in relativistic heavy ion collisions. Physics Letters B, 696(5):499 504, 2011.
[2] K. Aamodt et al. [ALICE Collaboration], arXiv:1105.3865 [nucl-ex].
[3] M. Luzum and J-Y Ollitrault, PRL 106, 102301 (2011)
[4] J.F. Grosse-Oetringhaus, proceedings in this volume.

How to prepare and submit an article for publication in an IOP journal using LaTeX 2ε

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Abstract. This document describes the preparation of an article using LaTeX 2ε and `iopart.cls` (the IOP LaTeX 2ε preprint class file). This class file is designed to help authors produce preprints in a form suitable for submission to any of the journals published by IOP Publishing. Authors submitting to any IOP journal, i.e. both single- and double-column ones, should follow the guidelines set out here. On acceptance, their TeX code will be converted to the appropriate format for the journal concerned.

1. Introduction: file preparation and submission

The `iopart` LaTeX 2ε article class file is provided to help authors prepare articles for submission to the IOP journals. Submission is not restricted to those using of this class file and articles prepared using any other class or style files can also be submitted. Use of the `iopart` class file does, however, help to speed the publication process and it is hoped it will make it easy for authors to prepare their articles. This document describes and demonstrates the use of `iopart.cls` to produce a preprint for submission and refereeing. The detailed formatting for print and web use will be undertaken by IOP as part of the production process after the article has been accepted for publication, but use of `iopart` does make this simpler.

1.1. What you will need to supply

Full details on how to submit files to a particular IOP journal are contained in the document *Guidelines for authors* which is discussed in section 1.4. Here we mention the key points you need to consider when preparing your files for submission.

1.1.1. **Text** The LaTeX source code of your paper with all figures included in the source code (see section 9.2). Although we recommend that authors use the `iopart` class file, articles prepared using almost any version of TeX or LaTeX can be handled.

- **Using LaTeX packages** Most LaTeX 2ε packages can be used if they are available in the normal distribution of LaTeX 2ε; however, if it is essential to use a non-standard package then any extra files needed to process the article must also be sent in. Authors should be aware that the final version will be printed on a different page size and using different fonts to the preprint version so that any special effects used should not contain material that is not easily scalable. Alterations to the source code will be made during the production process in order to conform to IOP house style and journal format.

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- do not use spaces in file names;
- include an extension to indicate the file type (e.g., .tex, .eps, .txt, etc);
- do not use any accented characters in file names; for example, á, ê, ñ, ö, etc because they can cause difficulties when processing your files.

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1.5. Obtaining the class file and documentation

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2. Preparing your article

Please follow these guidelines as closely as possible, particularly with regard to the preparation of the reference list.

At the start of the LaTeX source please include commented material to identify the journal, author and reference number if known. The first non-commented line should be `\documentclass[12pt]{iopart}` to load the preprint class file. Omitting `[12pt]` produces an article with the normal journal page and type sizes. The start of the article text is signalled by `\begin{document}`. Authors of very long articles may find it convenient to separate their article into a series of files each containing a section, each of which is called in turn by the primary file.

Authors may add their own macros at the start of an article provided they do not overwrite existing definitions and that they send copies of their new macros with their text file. Macros for the individual paper not included in a style file should be inserted in the preamble to the paper with comments to describe any complex or non-obvious ones. `iopart` can be used with other package files such as those loading the AMS extension fonts `msam` and `msbm` (these fonts provide the blackboard bold alphabet and various extra maths symbols as well as symbols useful in figure captions); an extra style file `iopams.sty` is provided to load these packages and provide extra definitions for bold Greek letters.

2.1. Double-column journals

Authors writing for double-column journals should use the `iopart` class file. Conversion from the single-column format to the double-column output required for printing will be done during the production process. However, authors should bear in mind that all mathematical formulae will need to be fitted into the width of a single column, so individual lines of equations should not occupy more than two thirds of the line width in this preprint form.

Table 1. Types of article defined in the `iopart.cls` class file.

Command	Type	Heading on first page
`\title{#1}`	Paper	—
`\review{#1}`	Review	REVIEW
`\topical{#1}`	Topical review	TOPICAL REVIEW
`\comment{#1}`	Comment	COMMENT
`\note{#1}`	Note	NOTE
`\paper{#1}`	Paper	—
`\prelim{#1}`	Preliminary communication	PRELIMINARY COMMUNICATION
`\rapid{#1}`	Rapid communication	RAPID COMMUNICATION
`\letter{#1}`	Letter	LETTER TO THE EDITOR
`\article{#1}{#2}`	Other articles	Whatever is entered as `#1`

3. The title and abstract page

The code for setting the title page information is slightly different from the normal default in LaTeX.

3.1. Titles and article types

The title is set using the command `\title{#1}`, where `#1` is the title of the article. The first letter of the title should be capitalized with the rest in lower case. Mathematical expressions within the title may be left in light-face type.

If the title is too long to use as a running head at the top of each page (apart from the first) a short form can be provided as an optional argument (in square brackets) before the full title, i.e. `\title[Short title]{Full title}`.

For article types other than papers, `iopart.cls` has a generic heading `\article[Short title]{TYPE}{Full title}` and the specific definitions given in table 1. In each case (apart from Letters to the Editor) an optional argument can be used immediately after the control sequence name to specify the short title; where no short title is given the full title will be used as the running head. For Letters use `\letter{Full title}`, no short title is required as the running head is automatically defined to be *Letter to the Editor*. The generic heading could be used for articles such as those presented at a conference or workshop, e.g.

```
\article[Short title]{WORKSHOP ON HIGH-ENERGY PHYSICS}{Title}
```

Footnotes to titles may be given, though acknowledgment of funding should be included in the acknowledgments section rather than here. A footnote can be included by using `\footnote{Text of footnote.}` immediately after the title.

3.2. Authors' names and addresses

The next information required is the list of authors' names and their affiliations. For the authors' names type `\author{#1}`, where `#1` is the list of all authors' names. The style for the names is initials then family name, with a comma after all but the last two

names, which are separated by 'and'. Initials should *not* be followed by full stops. First (given) names may be used if desired and Chinese-style names included in the form they should be printed in. If the authors are at different addresses a superscripted number, e.g. [1], `$^1$`, should be used after each name to reference the author to his/her address. If an author has additional information to appear as a footnote, such as a permanent address, a normal LaTeX footnote command should be given after the family name and address marker with this extra information.

The addresses of the authors' affiliations follow the list of authors. Each address is set by using `\address{#1}` with the address as the single parameter in braces. If there is more than one address then the appropriate superscripted number, followed by a space, should come at the start of the address.

Please also add the e-mail addresses for at least one of the authors. This is done by inserting the command `\ead{#1}` after the postal address(es) where `#1` is the e-mail address. See section 3.7 for sample coding. For more than one e-mail address, please use the command `\eads{\mailto{#1}, \mailto{#2}}` with `\mailto` surrounding each e-mail address.

3.3. The abstract

The abstract follows the addresses and should give readers concise information about the content of the article and indicate the main results obtained and conclusions drawn. It should be self-contained with no reference to figures, tables, equations, bibliographic references etc included and should not normally exceed 200 words. To indicate the start of the abstract type `\begin{abstract}` followed by the text of the abstract (not in braces). The abstract should normally be restricted to a single paragraph and is terminated by the command `\end{abstract}`

3.4. Subject classification numbers

Any Physics and Astronomy Classification System (PACS) codes or Mathematics Subject Classification (MSC) scheme numbers should come immediately after the abstract. Classification codes can greatly help in the choice of suitable referees and allocation of articles to subject areas. For *Inverse Problems* and *Nonlinearity* authors may use either PACS or MSC codes.

PACS or MSC numbers are included after the abstract using `\pacs{#1}` and `\ams{#1}` respectively.

After any classification numbers the command `\submitto{#1}` can be inserted, where `#1` is the journal name written in full or the appropriate control sequence as given in table B1. This command is not essential to the running of the file.

3.4.1. Information on PACS and MSC For more information on PACS and MSC see

- MSC: http://www.ams.org/msc

- PACS: http://www.aip.org/pacs

3.5. Keywords

Keywords should be provided for submissions to *Measurement Science and Technology, Physical Biology, Physiological Measurement*, and both parts of *Journal of Optics*. Add these as a new paragraph starting `\noindent{\it Keywords\/}:` after the end of the abstract.

3.6. Making a separate title page

The command `\maketitle` forces a page break after the point where it is inserted and so to keep the header material on a separate page from the body of the text insert `\maketitle` or `\newpage` before the start of the text. If `\maketitle` is not included the text of the article will start immediately after the abstract.

3.7. Sample coding for the start of an article

The code for the start of a title page of a typical paper might read:

```
\documentclass[12pt]{iopart}
\begin{document}
\title[The anomalous magnetic moment of the
neutrino]{The anomalous magnetic moment of the
neutrino and its relation to the solar neutrino problem}

\author{P J Smith$^1$, T M Collins$^2$,
R J Jones$^3$\footnote{Present address:
Department of Physics, University of Bristol, Tyndalls Park Road,
Bristol BS8 1TS, UK.} and Janet Williams$^3$}

\address{$^1$ Mathematics Faculty, Open University,
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\address{$^2$ Department of Mathematics,
Imperial College, Prince Consort Road, London SW7~2BZ, UK}
\address{$^3$ Department of Computer Science,
University College London, Gower Street, London WC1E~6BT, UK}
\ead{williams@ucl.ac.uk}

\begin{abstract}
...
\end{abstract}
\pacs{1315, 9440T}
\submitto{\JPG}
\maketitle
```

4. The text

4.1. Sections, subsections and subsubsections

The text of articles may be divided into sections, subsections and, where necessary, subsubsections. To start a new section, end the previous paragraph and then include `\section` followed by the section heading within braces. Numbering of sections is done *automatically* in the headings: sections will be numbered 1, 2, 3, etc, subsections will be numbered 2.1, 2.2, 3.1, etc, and subsubsections will be numbered 2.3.1, 2.3.2, etc. Cross references to other sections in the text should, where possible, be made using labels (see section 7) but can also be made manually. See section 5.7 for information on the numbering of displayed equations. Subsections and subsubsections are similar to sections but the commands are `\subsection` and `\subsubsection` respectively. Sections have a bold heading, subsections an italic heading and subsubsections an italic heading with the text following on directly.

```
\section{This is the section title}
\subsection{This is the subsection title}
```

The first section is normally an introduction, which should state clearly the object of the work, its scope and the main advances reported, with brief references to relevant results by other workers. In long papers it is helpful to indicate the way in which the paper is arranged and the results presented.

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Authors wishing to acknowledge assistance or encouragement from colleagues, special work by technical staff or financial support from organizations should do so in an unnumbered 'Acknowledgments' section immediately following the last numbered section of the paper. The command `\ack` sets the acknowledgments heading as an unnumbered section. For Letters `\ack` does not set a heading but leaves a line space and does not indent the next paragraph.

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Technical detail that it is necessary to include, but that interrupts the flow of the article, may be consigned to an appendix. Any appendices should be included at the end of the main text of the paper, after the acknowledgments section (if any) but before the reference list. If there are two or more appendices they should be called Appendix A, Appendix B, etc. Numbered equations will be in the form (A.1), (A.2), etc, figures will appear as figure A1, figure B1, etc and tables as table A1, table B1, etc.

The command `\appendix` is used to signify the start of the appendices. Thereafter `\section`, `\subsection`, etc, will give headings appropriate for an appendix. To obtain a simple heading of 'Appendix' use the code `\section*{Appendix}`. If it contains numbered equations, figures or tables the command `\appendix` should precede it and `\setcounter{section}{1}` must follow it.

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5. Mathematics

5.1. Two-line constructions

The great advantage of LaTeX over other text processing systems is its ability to handle mathematics to almost any degree of complexity. However, in order to produce an article suitable for publication both within a print journal and online, authors should exercise some restraint on the constructions used. Some equations using very small characters which are clear in a preprint style article may be difficult read in a smaller format or online at a relatively low resolution. For simple fractions in the text the solidus `/`, as in $\lambda/2\pi$, should be used instead of `\frac` or `\over`, care being taken to use parentheses where necessary to avoid ambiguity, for example to distinguish between $1/(n-1)$ and $1/n-1$. Exceptions to this are the proper fractions $\frac{1}{2}$, $\frac{1}{3}$, $\frac{3}{4}$, etc, which are better left in this form. In displayed equations horizontal lines are preferable to solidi provided

the equation is kept within a height of two lines. A two-line solidus should be avoided where possible; the construction $(\ldots)^{-1}$ should be used instead; for example use:

$$\frac{1}{M_{\mathrm{a}}}\left(\int_0^\infty \mathrm{d}\omega\ \frac{|S_o|^2}{N}\right)^{-1} \qquad \text{instead of} \qquad \frac{1}{M_{\mathrm{a}}}\Big/\int_0^\infty \mathrm{d}\omega\ \frac{|S_o|^2}{N}.$$

5.2. Roman and italic in mathematics

In mathematics mode LaTeX automatically sets variables in an italic font. In most cases authors should accept this italicization. However, there are some cases where it is better to use a Roman font; for instance, IOP journals use a Roman d for a differential d, a Roman e for an exponential e and a Roman i for the square root of −1. To accommodate this and to simplify the typing of equations we have provided some extra definitions. `\rmd`, `\rme` and `\rmi` now give Roman d, e and i respectively for use in equations, e.g. $\mathrm{i}x\mathrm{e}^{2x}\mathrm{d}x/\mathrm{d}y$ is obtained by typing `$\rmi x\rme^{2x}\rmd x/\rmd y$`.

Certain other common mathematical functions, such as cos, sin, det and ker, should appear in Roman type. LaTeX provides macros for most of these functions (in the cases above, `\cos`, `\sin`, `\det` and `\ker` respectively); we have also provided additional definitions for Tr, tr and O (`\Tr`, `\tr` and `\Or`, respectively).

Subscripts and superscripts should be in Roman type if they are labels rather than variables or characters that take values. For example in the equation

$$\epsilon_m = -g\mu_{\mathrm{n}}Bm$$

m, the z component of the nuclear spin, is italic because it can have different values whereas n is Roman because it is a label meaning nuclear (μ_{n} is the nuclear magneton).

5.3. Displayed equations in double-column journals

Authors should bear in mind that all mathematical formulae in double-column journals will need to be fitted into the width of a single column, so individual lines of equations should not occupy more than two thirds of the line width in this preprint form.

5.4. Special characters for mathematics

Bold italic characters can be used in our journals to signify vectors (rather than using an upright bold or an over arrow). To obtain this effect use `\bi{#1}` within maths mode, e.g. $\boldsymbol{ABCdef}$. If upright bold characters are required in maths use `\mathbf{#1}` within maths mode, e.g. $\mathbf{XYZabc}$. The calligraphic (script) uppercase alphabet is obtained with `\mathcal{AB}` or `\cal{CD}` ($\mathcal{ABCD}$).

The American Mathematical Society provides a series of extra symbol fonts to use with LaTeX and packages containing the character definitions to use these fonts. Authors wishing to use Fraktur or Blackboard Bold can include the appropriate AMS package (e.g. amsgen, amsfonts, amsbsy, amssymb) with a `\usepackage` command or add the command `\usepackage{iopams}` which loads the four AMS packages mentioned

Table 2. Other macros defined in IOP macros for use in maths.

Macro	Result	Description
`\fl`		Start line of equation full left
`\case{#1}{#2}`	$\frac{\#1}{\#2}$	Text style fraction in display
`\Tr`	Tr	Roman Tr (Trace)
`\tr`	tr	Roman tr (trace)
`\Or`	O	Roman O (of order of)
`\tdot{#1}`	$\dddot{x}$	Triple dot over character
`\lshad`	$[\![$	Text size left shadow bracket
`\rshad`	$]\!]$	Text size right shadow bracket

above and also provides definitions for extra bold characters (all Greek letters and some additional other symbols).

The package iopams uses the definition `\boldsymbol` in amsbsy which allows individual non-alphabetical symbols and Greek letters to be made bold within equations. The bold Greek lowercase letters are obtained with the commands `\balpha` ... `\bomega` (but note that bold eta is `\bfeta` rather than `\beta`) and the capitals with commands `\bGamma` ... `\bOmega`. Bold versions of the following symbols are predefined in iopams: bold partial `\bpartial`, bold 'ell' `\bell`, bold imath `\bimath`, bold jmath `\bjmath`, bold infinity `\binfty`, bold nabla `\bnabla`, bold centred dot `\bdot`, other characters are made bold using `\boldsymbol{\symbolname}`.

Please do not use the style file `amsmath.sty` (part of the AMSTeX package) in conjunction with `iopart.cls`. This will result in several errors. To make use of the macros defined in `amsmath.sty`, we have provided the file `setstack.sty` which reproduces the following useful macros from `amsmath.sty`:

```
\overset \underset \sideset \substack \boxed   \leftroot
\uproot  \dddot   \ddddot  \varrow   \harrow
```

Table 2 lists some other macros for use in mathematics with a brief description of their purpose.

5.5. Alignment of displayed equations

The normal style for aligning displayed equations is to align them left rather than centre them. The class file automatically does this and indents each line of a display. To make any line start at the left margin of the page, add `\fl` at its start (to indicate full left).

Using the `eqnarray` environment equations will naturally be aligned left without the use of any ampersands for alignment, see equations (1) and (8)

$$\alpha + \beta = \gamma^2 \tag{1}$$

$$\alpha^2 + 2\gamma + \cos\theta = \delta \tag{2}$$

This is the normal equation style for our journals.

Where some secondary alignment is needed, for instance a second part of an equation on a second line, a single ampersand is added at the point of alignment in each line (see (3) and (4)).

$$\alpha = 2\gamma^2 + \cos\theta + \frac{XY\sin\theta}{X + Y\cos\theta} \tag{3}$$

$$= \delta\theta PQ\cos\gamma. \tag{4}$$

Two points of alignment are possible using two ampersands for alignment (see (5) and (6)). Note in this case extra space `\qquad` is added before the second ampersand in the longest line (the top one) to separate the condition from the equation.

$$\alpha = 2\gamma^2 + \cos\theta + \frac{XY\sin\theta}{X + Y\cos\theta} \qquad \theta > 1 \tag{5}$$

$$= \delta\theta PQ\cos\gamma \qquad \theta \leq 1 \tag{6}$$

For a long equation which has to be split over more than one line the first line should start at the left margin, this is achieved by inserting `\fl` (full left) at the start of the line, the use of the alignment parameter `&` is not necessary unless some secondary alignment is needed.

$$\alpha + 2\gamma^2 = \cos\theta + \frac{XY\sin\theta}{X + Y\cos\theta} + \frac{XY\sin\theta}{X - Y\cos\theta} + + \left(\frac{XY\sin\theta}{X + Y\cos\theta}\right)^2 + \left(\frac{XY\sin\theta}{X - Y\cos\theta}\right)^2 \tag{7}$$

The Plain TeX command `\eqalign` can be used within an `equation` environment to obtain a multiline equation with a single centred number, for example

$$\begin{aligned} &\alpha + \beta = \gamma^2 \\ &\alpha^2 + 2\gamma + \cos\theta = \delta. \end{aligned} \tag{8}$$

5.6. Miscellaneous points

Exponential expressions, especially those containing subscripts or superscripts, are clearer if the notation exp(...) is used except for simple examples. For instance $\exp[\mathrm{i}(kx - \omega t)]$ and $\exp(z^2)$ are preferred to $\mathrm{e}^{\mathrm{i}(kx-\omega t)}$ and e^{z^2}, but e^x is acceptable. Similarly the square root sign $\sqrt{}$ should only be used with relatively simple expressions, e.g. $\sqrt{2}$ and $\sqrt{a^2 + b^2}$; in other cases the power 1/2 should be used; for example, $[(x^2 + y^2)/xy(x - y)]^{1/2}$.

It is important to distinguish between $\ln = \log_\mathrm{e}$ and $\lg = \log_{10}$. Braces, brackets and parentheses should be used in the following order: $\{[(\ )]\}$. The same ordering of brackets should be used within each size. However, this ordering can be ignored if the brackets have a special meaning (e.g. if they denote an average or a function). Decimal fractions should always be preceded by a zero: for example 0.123 **not** .123. For long numbers commas are not inserted but instead a thin space is added after every third character away from the position of the decimal point unless this leaves a single separated character: e.g. 60 000, 0.123 456 78 but 4321 and 0.7325.

Equations should be followed by a full stop (periods) when at the end of a sentence.

5.7. Equation numbering

LaTeX provides facilities for automatically numbering equations and these should be used where possible. Sequential numbering (1), (2), etc, is the default numbering system although, if the command `\eqnobysec` is included in the preamble, equation numbering by section is obtained, e.g. (2.1), (2.2), etc. In articles with several appendices equation numbering by section is useful in the appendices even when sequential numbering has been used throughout the main body of the text and is switched on by the `\appendix` command. Equation numbering by section *must* be used for *Reports on Progress in Physics*. When referring to an equation in the text it is not normally necessary to include the word equation before the number, which should be parentheses. Do not use abbreviations such as eqn or eq. When cross-referencing is used, `(\ref{<label>})` will produce '(`<eqnum>`)', `\eref{<label>}` produces '(`<eqnum>`)' and `\Eref{<label>}` produces 'Equation (`<eqnum>`)', where `<label>` is the label to produce equation number `<eqnum>`.

Sometimes it is useful to number equations as parts of the same basic equation. This can be accomplished by inserting the commands `\numparts` before the equations concerned and `\endnumparts` when reverting to the normal sequential numbering. The equations below show the previous equations numbered as separate parts using `\numparts ... \endnumparts` and the `eqnarray` environment

$$T_{11} = (1+P_{\mathrm{e}})I_{\uparrow\uparrow} - (1-P_{\mathrm{e}})I_{\uparrow\downarrow} \tag{9a}$$

$$T_{-1-1} = (1+P_{\mathrm{e}})I_{\downarrow\downarrow} - (1-P_{\mathrm{e}})I_{\uparrow\downarrow} \tag{9b}$$

$$S_{11} = (3+P_{\mathrm{e}})I_{\downarrow\uparrow} - (3-P_{e})I_{\uparrow\uparrow} \tag{9c}$$

$$S_{-1-1} = (3+P_{\mathrm{e}})I_{\uparrow\downarrow} - (3-P_{\mathrm{e}})I_{\downarrow\downarrow} \tag{9d}$$

5.8. Miscellaneous extra commands for displayed equations

The `\cases` command of Plain TeX is available for use with LaTeX but has been amended slightly to increase the space between the equation and the condition. Equation (10) demonstrates simply the output from the `\cases` command

$$X = \begin{cases} 1 & \text{for } x \geq 0 \\ -1 & \text{for } x < 0 \end{cases} \tag{10}$$

To obtain text style fractions within displayed maths the command `\case{#1}{#2}` can be used (see equations (2) and (5)) instead of the usual `\frac{#1}{#2}` command or `{#1 \over #2}`.

When two or more short equations are on the same line they should be separated by a 'qquad space' (`\qquad`), rather than `\quad` or any combination of `\,`, `\>`, `\;` and `\ `.

6. Referencing

Two different styles of referencing are in common use: the Harvard alphabetical system and the Vancouver numerical system. All IOP journals allow the use of the Harvard or Vancouver system (authors should use the style they are comfortable with), apart from the following journals

- *Physics in Medicine and Biology*
- *Physiological Measurement*

for which authors must use the Harvard referencing style.

6.1. Alphabetical (Harvard) system

In the Harvard system the name of the author appears in the text together with the year of publication. As appropriate, either the date or the name and date are included within parentheses. Where there are only two authors both names should be given in the text; if there are more than two authors only the first name should appear followed by '*et al*' (which can be obtained by typing `\etal`). When two or more references to work by one author or group of authors occur for the same year they should be identified by including a, b, etc after the date (e.g. 1986a). If several references to different pages of the same article occur the appropriate page number may be given in the text, e.g. Kitchen (1982, p 39).

The reference list at the end of an article consists of an unnumbered 'References' section containing an alphabetical listing by authors' names and in date order for each author or group of identical authors. The reference list in the preprint style is started by including the command `\section*{References}` and then `\begin{harvard}`. Individual references start with `\item[]` and the reference list is completed with `\end{harvard}`. There is also a shortened form of the coding; `\section*{References}` and `\begin{harvard}` can be replaced by the single command `\References` and `\end{harvard}` can be shortened to `\endrefs`.

6.2. Numerical (Vancouver) system

In the numerical system references are numbered sequentially throughout the text. The numbers occur within square brackets and one number can be used to designate several references. A numerical reference list in the `iopart` style is started by including the command `\section*{References}` and then `\begin{thebibliography}{<num>}`, where `<num>` is the largest number in the reference list (or any other number with the same number of digits). The reference list gives the references in numerical, not alphabetical, order and is completed by `\end{thebibliography}`. Short forms of the commands are again available: `\Bibliography{<num>}` can be used at the start of the references section and `\endbib` at the end.

A variant of this system is to use labels instead of numbers within square brackets, this method is allowed although not recommended.

6.3. BiBTeX

Note that for the journals lised at the start of section 6 authors should use the appropriate `.bst` file to produce references in the correct style—see section 1.1.3 for a list of reccommended `.bst` files.

6.4. References, general

A complete reference should provide the reader with enough information to locate the article concerned. Titles of journal articles can also be included and are required for *Inverse problems, Journal of Neural Engineering, Measurement Science and Technology, Physical Biology, Physics in Medicine and Biology* and *Physiological Measurement*. Final page numbers of references are required for *Reports on Progress in Physics* and *Physiological Measurement*.

Up to ten authors may be given in a particular reference; where there are more than ten only the first should be given followed by '*et al*'. If an author is unsure of an abbreviation and the journal is not given in appendix B, it is best to leave the title in full.

The terms *loc. cit.* and *ibid.* should not be used. Unpublished conferences and reports should generally not be included in the reference list if a published version of the work exists. Articles in the course of publication should include the article title and the journal of publication, if known. A reference to a thesis submitted for a higher degree may be included if it has not been superseded by a published paper but the institution where the work was done should be included.

The basic structure of a reference in the reference list is the same in both the alphabetical and numerical systems, the only difference the code at the start of the reference. Alphabetic references are preceded by `\item[]`, numeric by `\bibitem{label}` or just `\item` to generate a number or `\nonum` where a reference is not the first in a group of references under the same number.

Cross referencing between the text and the reference list is most useful in the numeric system but is not necessary for alphabetic referencing in the Harvard system as adding or deleting a reference does not normally change any of the other references. Care should, however, be taken to make sure that the text citations match the reference list and vice versa.

Note that footnotes to the text should not be included in reference list, but should appear at the bottom of the relevant page by using the `\footnote` command.

6.5. References to journal articles

A normal reference to a journal article contains three changes of font: the authors and date appear in Roman type, the journal title in italic, the volume number in bold and the page numbers in Roman again. A typical journal entry would be:

Cisneros A 1971 *Astrophys. Space Sci.* **10** 87

which would be obtained by typing, within the references environment

```
\item[] Cisneros A 1971 {\it Astrophys. Space Sci.} {\bf 10} 87
```

Features to note are the following.

(i) The authors should be in the form surname (with only the first letter capitalized) **followed** by the initials with **no** periods after the initials. Authors should be separated by a comma except for the last two which should be separated by 'and' with no comma preceding it. For journals that accept titles of articles in the reference list, the title should be in Roman (upright) lower case letters, except for an initial capital, and should follow the date.

(ii) The year of publication follows the authors and is not in parentheses. An article title (in Roman) would follow the year.

(iii) The journal is in italic and is abbreviated. Appendix B gives a list of macros that will give the correct abbreviation for many of the common journals. If a journal has several parts denoted by different letters the part letter should be inserted after the journal in Roman type, e.g. *Phys. Rev.* A.

(iv) The volume number is bold; the page number is Roman. Both the initial and final page numbers should be given where possible. The final page number should be in the shortest possible form and separated from the initial page number by an en rule (`--`), e.g. 1203–14.

(v) Where there are two or more references with identical authors, the authors' names should be repeated for the second and subsequent references. Each individual publication should be presented as a separate reference, although in the numerical system one number can be used for several references. This facilitates linking in the electronic version of the journal.

6.6. Electronic journal references

These often do not always follow the conventional *year-journal-volume-page numbers* pattern. Some examples are:

[1] Carlip S and Vera R 1998 *Phys. Rev.* D **58** 011345
[2] Davies K and Brown G 1997 *J. High Energy Phys.* JHEP12(1997)002
[3] Hannestad S 2005 *J. Cosmol. Astropart. Phys.* JCAP02(2005)011
[4] Hilhorst H J 2005 *J. Stat. Mech.* L02003
[5] Gundlach C 1999 *Liv. Rev. Rel.* 1994-4

6.7. Preprint references

Preprint may be referenced but if the article concerned has been published in a peer-reviewed journal, that reference should take precedence. If only a preprint reference can be given, it is helpful to include the article title. Examples are:

[1] Neilson D and Choptuik M 2000 *Class. Quantum Grav.* **17** 761 (*Preprint* gr-qc/9812053)
[2] Harrison M 1999 Dipheomorphism-invariant manifolds *Preprint* hep-th/9909196

6.8. References to books, conference proceedings and reports

References to books, proceedings and reports are similar, but have only two changes of font. The authors and date of publication are in Roman, the title of the book is in italic, and the editors, publisher, town of publication and page number are in Roman. A typical reference to a book and a conference paper might be

Dorman L I 1975 *Variations of Galactic Cosmic Rays* (Moscow: Moscow State University Press) p 103
Caplar R and Kulisic P 1973 *Proc. Int. Conf. on Nuclear Physics (Munich)* vol 1 (Amsterdam: North-Holland/American Elsevier) p 517

which would be obtained by typing

```
\item[] Dorman L I 1975 {\it Variations of Galactic Cosmic Rays}
(Moscow: Moscow State University Press) p~103
\item[] Caplar R and Kulisic P 1973 {\it Proc. Int. Conf. on Nuclear
Physics (Munich)} vol~1 (Amsterdam: North-Holland/American
Elsevier) p~517
```

respectively.

Features to note are the following.

(i) Book titles are in italic and should be spelt out in full with initial capital letters for all except minor words. Words such as Proceedings, Symposium, International, Conference, Second, etc should be abbreviated to Proc., Symp., Int., Conf., 2nd, respectively, but the rest of the title should be given in full, followed by the date of the conference and the town or city where the conference was held. For Laboratory Reports the Laboratory should be spelt out wherever possible, e.g. *Argonne National Laboratory Report*.

(ii) The volume number as, for example, vol 2, should be followed by the editors, if any, in a form such as ed A J Smith and P R Jones. Use *et al* if there are more than two editors. Next comes the town of publication and publisher, within brackets and separated by a colon, and finally the page numbers preceded by p if only one number is given or pp if both the initial and final numbers are given.

(iii) If a book is part of a series (for examples, *Springer Tracts in Modern Physics*), the series title and volume number is given in parentheses after the book title. Whereas for an individual volume in a multivolume set, the set title is given first, then the volume title.

Morse M 1996 Supersonic beam sources *Atomic Molecular and Optical Physics* (*Experimental Methods in the Physical Sciences* vol 29) ed F B Dunning and R Hulet (San Diego: Academic)

Fulco C E, Liverman C T and Sox H C (eds) 2000 *Gulf War and Health* vol 1 *Depleted Uranium, Pyridostigmine Bromide, Sarin, and Vaccines* (Washington, DC: The National Academies Press)

7. Cross referencing

The facility to cross reference items in the text is very useful when composing articles as the precise form of the article may be uncertain at the start and revisions and amendments may subsequently be made. LaTeX provides excellent facilities for doing cross-referencing and these can be very useful in preparing articles.

7.1. References

Cross referencing is useful for numeric reference lists because, if it is used, adding another reference to the list does not then involve renumbering all subsequent references. It is not necessary for referencing in the Harvard system where the final reference list is alphabetical and normally no other changes are necessary when a reference is added or deleted. Two passes are necessary initially to get the cross references right but once they are correct a single run is usually sufficient provided an `.aux` file is available and the file is run to the end each time. `\cite` and `\bibitem` are used to link citations in the text with their entry in the reference list; if the reference list contains an entry `\bibitem{label}`, then `\bibitem{label}` will produce the correct number in the reference list and `\cite{label}` will produce the number within square brackets in the text. `label` may contain alphabetic letters, or punctuation characters but must not contain spaces or commas. It is also recommended that the underscore character _ is not used in cross referencing. Thus labels for the form `eq:partial`, `fig:run1`, `eq:dy'`, etc, may be used. When several references occur together in the text `\cite` may be used with multiple labels with commas but no spaces separating them; the output will be the numbers within a single pair of square brackets with a comma and a thin space separating the numbers. Thus `\cite{label1,label2,label4}` would give [1, 2, 4]. Note that no attempt is made by the style file to sort the labels and no shortening of groups of consecutive numbers is done. Authors should therefore try to use multiple labels in the correct order.

The numbers for the cross referencing are generated in the order the references appear in the reference list, so that if the entries in the list are not in the order in which the references appear in the text then the numbering within the text will not be sequential. To correct this change the ordering of the entries in the reference list and then rerun *twice*.

7.2. Equation numbers, sections, subsections, figures and tables

Labels for equation numbers, sections, subsections, figures and tables are all defined with the `\label{label}` command and cross references to them are made with the `\ref{label}` command.

Table 3. Alternatives to the normal references `\ref` and the text generated by them. Note it is not normally necessary to include the word equation before an equation number except where the number starts a sentence. The versions producing an initial capital should only be used at the start of sentences.

Reference	Text produced
`\eref{<label>}`	(`<num>`)
`\Eref{<label>}`	Equation (`<num>`)
`\fref{<label>}`	figure `<num>`
`\Fref{<label>}`	Figure `<num>`
`\sref{<label>}`	section `<num>`
`\Sref{<label>}`	Section `<num>`
`\tref{<label>}`	table `<num>`
`\Tref{<label>}`	Table `<num>`

Any section, subsection, subsubsection, appendix or subappendix command defines a section type label, e.g. 1, 2.2, A2, A1.2 depending on context. A typical article might have in the code of its introduction 'The results are discussed in section~`\ref{disc}`.' and the heading for the discussion section would be:

```
\section{Results}\label{disc}
```

Labels to sections, etc, may occur anywhere within that section except within another numbered environment. Within a maths environment labels can be used to tag equations which are referred to within the text.

In addition to the standard `\ref{<label>}` the abbreviated forms given in the table 3 are available for reference to standard parts of the text

8. Tables and table captions

Tables are numbered serially and referred to in the text by number (table 1, etc, **not** tab. 1). Each table should have an explanatory caption which should be as concise as possible. If a table is divided into parts these should be labelled (*a*), (*b*), (*c*), etc but there should be only one caption for the whole table, not separate ones for each part.

In the preprint style the tables may be included in the text or listed separately after the reference list starting on a new page.

8.1. The basic table format

The standard form for a table is:

```
\begin{table}
\caption{\label{label}Table caption.}
\begin{indented}
\item[]\begin{tabular}{@{}llll}
\br
Head 1&Head 2&Head 3&Head 4\\
```

Table 4. A simple example produced using the standard table commands and `\lineup` to assist in aligning columns on the decimal point. The width of the table and rules is set automatically by the preamble.

A	*B*	*C*	*D*	*E*	*F*	*G*
23.5	60	0.53	−20.2	−0.22	1.7	14.5
39.7	−60	0.74	−51.9	−0.208	47.2	146
123.7	0	0.75	−57.2	—	—	—
3241.56	60	0.60	−48.1	−0.29	41	15

```
\mr
1.1&1.2&1.3&1.4\\
2.1&2.2&2.3&2.4\\
\br
\end{tabular}
\end{indented}
\end{table}
```

Points to note are:

(i) The caption comes before the table. It should have a period at the end.

(ii) Tables are normally set in a smaller type than the text. The normal style is for tables to be indented. This is accomplished by using `\begin{indented}` ... `\end{indented}` and putting `\item[]` before the start of the tabular environment. Omit these commands for any tables which will not fit on the page when indented.

(iii) The default is for columns to be aligned left and adding `@{}` omits the extra space before the first column.

(iv) Tables have only horizontal rules and no vertical ones. The rules at the top and bottom are thicker than internal rules and are set with `\br` (bold rule). The rule separating the headings from the entries is set with `\mr` (medium rule).

(v) Numbers in columns should be aligned on the decimal point; to help do this a control sequence `\lineup` has been defined which sets `\0` equal to a space the size of a digit, `\m` to be a space the width of a minus sign, and `\-` to be a left overlapping minus sign. `\-` is for use in text mode while the other two commands may be used in maths or text. (`\lineup` should only be used within a table environment after the caption so that `\-` has its normal meaning elsewhere.) See table 4 for an example of a table where `\lineup` has been used.

8.2. Simplified coding and extra features for tables

The basic coding format can be simplified using extra commands provided in the `iopart` class file. The commands up to and including the start of the tabular environment can be replaced by

```
\Table{\label{label}Table caption}
```

Table 5. A table with headings spanning two columns and containing notes. To improve the visual effect a negative skip (\ns) has been put in between the lines of the headings. Commands set-up by \lineup are used to aid alignment in columns. \lineup is defined within the \Table definition.

Nucleus	Thickness ($mg\,cm^{-2}$)	Composition	Separation energies	
			γ, n (MeV)	γ, 2n (MeV)
^{181}Ta	19.3 ± 0.1[a]	Natural	7.6	14.2
^{208}Pb	3.8 ± 0.8[b]	99% enriched	7.4	14.1
^{209}Bi	2.86 ± 0.01[b]	Natural	7.5	14.4

[a] Self-supporting.
[b] Deposited over Al backing.

this also activates the definitions within \lineup. The final three lines can also be reduced to \endTable or \endtab. Similarly for a table which does not fit in when indented \fulltable{\label{label}caption} ... \endfulltable or \endtab can be used. LaTeX optional positional parameters can, if desired, be added after \Table{\label{label}caption} and \fulltable{\label{label}caption}.

\centre{#1}{#2} can be used to centre a heading #2 over #1 columns and \crule{#1} puts a rule across #1 columns. A negative space \ns is usually useful to reduce the space between a centred heading and a centred rule. \ns should occur immediately after the \\ of the row containing the centred heading (see code for table 5). A small space can be inserted between rows of the table with \ms and a half line space with \bs (both must follow a \\ but should not have a \\ following them).

Units should not normally be given within the body of a table but given in brackets following the column heading; however, they can be included in the caption for long column headings or complicated units. Where possible tables should not be broken over pages. If a table has related notes these should appear directly below the table rather than at the bottom of the page. Notes can be designated with footnote symbols (preferable when there are only a few notes) or superscripted small roman letters. The notes are set to the same width as the table and in normal tables follow after \end{tabular}, each note preceded by \item[]. For a full width table \noindent should precede the note rather than \item[]. To simplify the coding \tabnotes can, if desired, replace \end{tabular} and \endtabnotes replaces \end{indented}\end{table}.

If all the tables are grouped at the end of a document the command \Tables is used to start a new page and set a heading 'Tables and table captions'. If the tables follow an appendix then add the command \noappendix to revert to normal style numbering.

9. Figures and figure captions

Figures (with their captions) can be incorporated into the text at the appropriate position or grouped together at the end of the article. If the figures are at the end of the article and follow an appendix then add the command `\noappendix` to revert to normal style numbering.

9.1. Using copyright material

If you wish to illustrate your paper using material for which you do not own the copyright then you must seek permission from the copyright holder, usually both the author and the publisher of the previous work. It is the author's responsibility to obtain copyright permissions and this should be done prior to submitting your paper. If you have obtained permission, please provide full details of the permission granted—for example, copies of the text of any e-mails or a copy of any letters you may have received. Figure captions must include an acknowledgment of the original source of the material even when permission to use has been obtained.

9.2. Inclusion of graphics files

Using the `graphicx` package graphics files can be included within figure and center environments at an appropriate point within the text using code such as:

```
\includegraphics{file.eps}
```

The `graphicx` package supports various optional arguments to control the appearance of the figure. Other similar packages can also be used (e.g. `graphics`, `epsf`). For more detail about graphics inclusion see the documentation of the `graphicx` package, refer to one of the books on LaTeX [1] or download some of the excellent free documentation available via the Comprehensive TeX Archive Network (CTAN) http://www.ctan.org—in particular see [2]. IOP's graphics guidelines, *Preparing graphics for IOP journals*, provide further information on preparing EPS files—a copy should have accompanied this document but it may be download from authors.iop.org.

9.3. Captions

Each figure should have a brief caption describing it and, if necessary, interpreting the various lines and symbols on the figure. As much lettering as possible should be removed from the figure itself and included in the caption. If a figure has parts, these should be labelled (*a*), (*b*), (*c*), etc and all parts should be described within a single caption. Table 6 gives the definitions for describing symbols and lines often used within figure captions (more symbols are available when using the optional packages loading the AMS extension fonts).

Table 6. Control sequences to describe lines and symbols in figure captions.

Control sequence	Output	Control sequence	Output
`\dotted`	·····	`\opencircle`	○
`\dashed`	- - - -	`\opentriangle`	△
`\broken`	– – –	`\opentriangledown`	▽
`\longbroken`	— — —	`\fullsquare`	■
`\chain`	— · —	`\opensquare`	□
`\dashddot`	— · · —	`\fullcircle`	●
`\full`	——	`\opendiamond`	♢

9.4. Supplementary Data

All of our journals encourage authors to submit supplementary data attachments to enhance the online versions of published research articles. Supplementary data enhancements typically consist of video clips, animations or data files, tables of extra information or extra figures. They can add to the reader's understanding and present results in attractive ways that go beyond what can be presented in the print version of the journal. The printed journal remains the archival version, and supplementary data items are supplements which enhance a reader's understanding of the paper but are not essential to that understanding. For electronic-only journals, supplementary data attachments may be used to convey essential information. Guidelines on supplementary data file formats are contained in the document *Guidelines for authors* which can be accessed online by going to authors.iop.org.

Appendix A. List of macros for formatting text, figures and tables

Table A1. Macros available for use in text. Parameters in square brackets are optional.

Macro name	Purpose
`\title[#1]{#2}`	Title of article and short title (optional)
`\paper[#1]{#2}`	Title of paper and short title (optional)
`\letter{#1}`	Title of Letter to the Editor
`\comment[#1]{#2}`	Title of Comment and short title (optional)
`\topical[#1]{#2}`	Title of Topical Review and short title (optional)
`\review[#1]{#2}`	Title of review article and short title (optional)
`\note[#1]{#2}`	Title of Note and short title (optional)
`\prelim[#1]{#2}`	Title of Preliminary Communication & short title
`\author{#1}`	List of all authors
`\article[#1]{#2}{#3}`	Type and title of other articles and short title (optional)
`\address{#1}`	Address of author
`\pacs{#1}`	PACS classification codes
`\pacno{#1}`	Single PACS classification code
`\ams{#1}`	Mathematics Classification Scheme
`\submitto{#1}`	'Submitted to' message
`\maketitle`	Creates title page
`\begin{abstract}`	Start of abstract
`\end{abstract}`	End of abstract
`\nosections`	Inserts space before text when no sections
`\section{#1}`	Section heading
`\subsection{#1}`	Subsection heading
`\subsubsection{#1}`	Subsubsection heading
`\appendix`	Start of appendixes
`\ack`	Acknowledgments heading
`\References`	Heading for reference list
`\begin{harvard}`	Start of alphabetic reference list
`\end{harvard}`	End of alphabetic reference list
`\begin{thebibliography}{#1}`	Start of numeric reference list
`\end{thebibliography}`	End of numeric reference list
`\etal`	*et al* for text and reference lists
`\nonum`	Unnumbered entry in numerical reference list

Table A2. Macros defined within `iopart.cls` for use with figures and tables.

Macro name	Purpose
`\Figures`	Heading for list of figure captions
`\Figure{#1}`	Figure caption
`\Tables`	Heading for tables and table captions
`\Table{#1}`	Table caption
`\fulltable{#1}`	Table caption for full width table
`\endTable`	End of table created with `\Table`
`\endfulltab`	End of table created with `\fulltable`
`\endtab`	End of table
`\br`	Bold rule for tables
`\mr`	Medium rule for tables
`\ns`	Small negative space for use in table
`\centre{#1}{#2}`	Centre heading over columns
`\crule{#1}`	Centre rule over columns
`\lineup`	Set macros for alignment in columns
`\m`	Space equal to width of minus sign
`\-`	Left overhanging minus sign
`\0`	Space equal to width of a digit

Appendix B. Control sequences for journal abbreviations

Table B1. Abbreviations for the IOP journals.

Macro name	Short form of journal title	Years relevant
Current journals		
\CQG	Class. Quantum Grav.	
\EJP	Eur. J. Phys.	
\IP	Inverse Problems	
\JHEP	J. High Energy Phys.	1999 and onwards
\JMM	J. of Michromech. and Microeng.	
\JNE	J. Neural Eng.	
\JOA	J. Opt. A: Pure and Applied Opt.	1998 and onwards
\JOB	J. Opt. B: Quantum and Semiclass. Opt.	1999 and onwards
\JPA	J. Phys. A: Math. Gen.	
\jpb	J. Phys. B: At. Mol. Opt. Phys.	1988 and onwards
\JPCM	J. Phys: Condens. Matter	1989 and onwards
\JPD	J. Phys. D: Appl. Phys.	
\jpg	J. Phys. G: Nucl. Part. Phys.	1989 and onwards
\MSMSE	Modelling Simul. Mater. Sci. Eng.	
\MST	Meas. Sci. Technol.	1990 and onwards
\NJP	New J. Phys.	1999 and onwards
\NL	Nonlinearity	
\NT	Nanotechnology	
\PB	Phys. Biol.	
\PM	Physiol. Meas.	
\PMB	Phys. Med. Biol.	
\PPCF	Plasma Physics and Controlled Fusion	
\PSST	Plasma Sources Sci. Technol.	
\RPP	Rep. Prog. Phys.	
\SST	Semicond. Sci. Technol.	
\SMS	Smart Mater. Struct.	
\SUST	Supercond. Sci. Technol.	
No Longer Published		
\JPB	J. Phys. B: At. Mol. Phys.	1968–1987
\JPC	J. Phys. C: Solid State Phys.	1968–1988
\JPE	J. Phys. E: Sci. Instrum.	1968–1989
\JPF	J. Phys. F: Met. Phys.	1971–1988
\JPG	J. Phys. G: Nucl. Phys.	1975–1988
\PAO	Pure and Applied Opt.	1992–1998
\QO	Quantum Opt.	1989–1994
\QSO	Quantum and Semiclass. Opt.	1995–1998

Table B2. Abbreviations for some more common non-IOP journals.

Macro name	Short form of journal
`\AC`	Acta Crystallogr.
`\AM`	Acta Metall.
`\AP`	Ann. Phys., Lpz
`\APNY`	Ann. Phys., NY
`\APP`	Ann. Phys., Paris
`\CJP`	Can. J. Phys.
`\GRG`	Gen. Rel. Grav.
`\JAP`	J. Appl. Phys.
`\JCP`	J. Chem. Phys.
`\JJAP`	Japan. J. Appl. Phys.
`\JMMM`	J. Magn. Magn. Mater.
`\JMP`	J. Math. Phys.
`\JOSA`	J. Opt. Soc. Am.
`\JP`	J. Physique
`\JPhCh`	J. Phys. Chem.
`\JPSJ`	J. Phys. Soc. Japan
`\JQSRT`	J. Quant. Spectrosc. Radiat. Transfer
`\NC`	Nuovo Cimento
`\NIM`	Nucl. Instrum. Methods
`\NP`	Nucl. Phys.
`\PF`	Phys. Fluids
`\PL`	Phys. Lett.
`\PR`	Phys. Rev.
`\PRL`	Phys. Rev. Lett.
`\PRS`	Proc. R. Soc.
`\PS`	Phys. Scr.
`\PSS`	Phys. Status Solidi
`\PTRS`	Phil. Trans. R. Soc.
`\RMP`	Rev. Mod. Phys.
`\RSI`	Rev. Sci. Instrum.
`\SSC`	Solid State Commun.
`\SPJ`	Sov. Phys.–JETP
`\ZP`	Z. Phys.

References

[1] Goosens M, Rahtz S and Mittelbach F 1997 *The LaTeX Graphics Companion* (Reading, MA: Addison-Wesley)

[2] Reckdahl K 1997 *Using Imported Graphics in LaTeX* (search CTAN for the file 'epslatex.pdf')